

# Human Motion Perception: Error Metrics and Neural Models

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Pilots and astronauts have to make accurate judgments of their self-motion (or of that of the craft they are controlling) to navigate safely and effectively. In many critical aerospace tasks, such as flying a helicopter at low altitude under low-contrast conditions or landing the shuttle after several weeks of adaptation to microgravity, human performance in self-motion estimation is pushed to its limits, yet any perceptual error could have disastrous consequences. The goal of this research project is to identify visual conditions under which humans are likely to make perceptual errors in visual motion judgments and to understand at the neural level why these errors occur, as part of a strategy to develop methods of preventing or mitigating them. The specific aims are (1) to develop predictive biologically based models of human performance in heading estimation and

related motion perception tasks, and (2) to identify empirically those conditions that lead to human error, as part of an effort to test, refine, and validate some models, while ruling out others. The availability of validated quantitative models of human self-motion perception will aid in the design of training regimes for pilots, in the development of displays and automation systems that interact more effectively with human pilots while they fly aircraft or spacecraft, and in the evolution of artificial vision systems based on the massively parallel architecture of the human brain.

In collaboration with Dr. Thompson at the University of York in the United Kingdom, human errors associated with low-contrast motion stimuli (such as motion seen through fog) have been identified. In FY97, by showing that flicker and speed

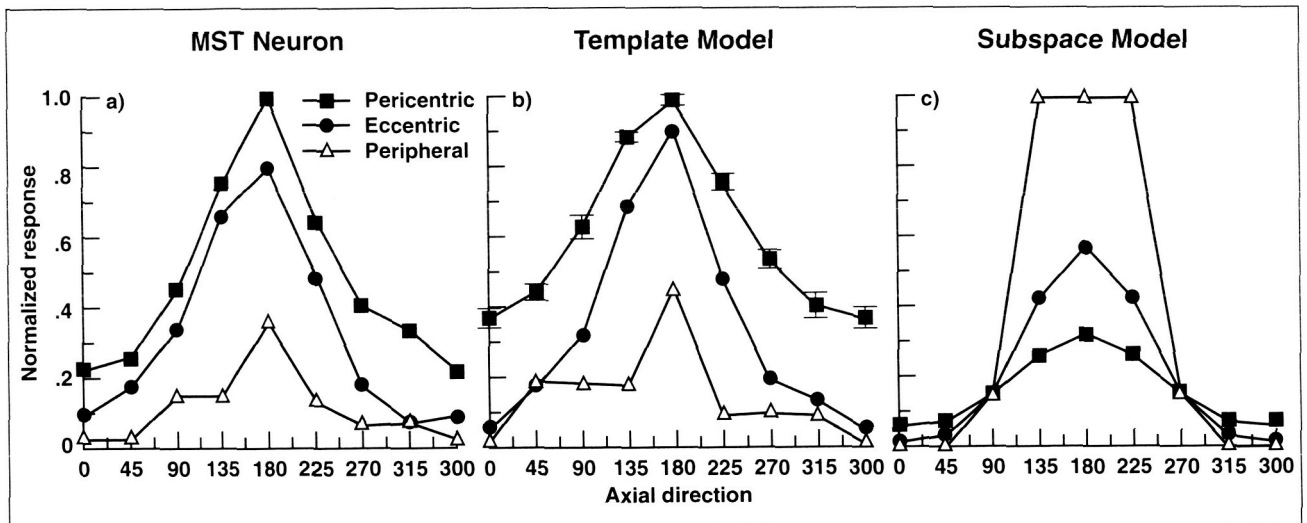


Fig. 1. (a) The responses of a real neuron in MST area as a function of heading direction along a series of axial directions at three eccentricities (from Duffy and Wurtz, 1995); (b) the responses of a template model "neuron" to the same set of visual stimuli (from Perrone and Stone, 1994); and (c) the response of a subspace model "neuron" to the same set of visual stimuli (from Lappe and Rauschke, 1993).

perception errors have the opposite contrast dependence, the class of models of human speed perception that rely on flicker to derive motion can be ruled out almost entirely. In collaboration with Dr. Perrone at the University of Waikato in New Zealand, a neural "template" model of human visual self-motion estimation was developed in 1994. In FY97, it was demonstrated that the neural elements within the Ames-developed template model can quantitatively mimic the response properties of neurons in the Medial Superior Temporal area, a visual processing area within the primate brain thought to underlie

self-motion perception, whereas the neural units of subspace models cannot (see figure). The template model also correctly predicts that during self-motion along a curved path, human perception will show a small bias in the direction of the turn, but will not show errors associated with discontinuities in the environmental layout (as is predicted by decomposition models).

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## Eye Movement Metrics of Human Motion Perception and Search

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Visual display systems provide critical information to pilots, astronauts, and air traffic controllers. The goal of this research project is to develop precise and reliable quantitative metrics of human performance based on nonintrusive eye-movement monitoring that can be used in applied settings. The specific aims are (1) to refine the hardware, optics, and software of eye-trackers to allow the nonintrusive acquisition of high-temporal and high-spatial precision eye-position data; (2) to measure quantitatively the links between eye-movement data and perceptual-performance data during tracking and search tasks; and (3) to develop biologically based computational models of human perceptual and eye-movement performance. Validated quantitative models of human visual perception and eye-movement performance will assist in designing computer and other display systems optimized for specific human tasks, in the development of eye-movement-controlled machine interfaces, and in the evolution of artificial vision systems.

In FY97, considerable progress was made in the technical effort to improve the spatial and temporal resolution of infrared video-based systems. In collaboration with ISCAN Inc., a high-speed infrared

video-based prototype eye-tracker was benchmarked to have a precision of 0.12 degree at a 240-hertz sampling rate, although with a limited range of approximately  $\pm 5$  degrees. In collaboration with Dr. Krauzlis at the National Eye Institute, benchmark data from the state-of-the-art invasive eye-tracker (an eye-coil system) were gathered for comparison.

By measuring direction judgments and eye movements simultaneously, the use of signal-detection theory to predict the errors in direction judgments from eye movements was validated. Preliminary evidence suggests that the spatiotemporal integration rule used to drive pursuit eye movements is not simple vector averaging and, at least for luminance-defined (black-and-white) targets, appears to be similar to that used for perception. However, perception and eye movements may not share the same motion processing for color and contrast-defined targets. In collaboration with Dr. Eckstein of the Cedars-Sinai Medical Center, signal-detection theory was also applied to a search (target-location) task. The perceptual judgments and eye movements follow similar trends. As the figure shows, in an easy condition both the first eye movement and the final